

THE AMERICAN METEOROLOGICAL JOURNAL.

A MONTHLY REVIEW OF METEOROLOGY.

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THE AMERICAN METEOROLOGICAL JOURNAL.

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No. 12.

ICE-COLUMNS IN GRAVELLY SOIL.

PROF. CLEVELAND ABBE.

A VERY pretty subject for observational elucidation, during the spring and fall, consists in studying the true method of formation of the little slender columns of ice that are found at the surface of gravelly soil in moist places after a clear cool night. The best account hitherto given of this phenomenon is that by Dr. John Leconte in the *Proc. Amer. Assoc. Adv. Sci.*, 1850, Vol. III. pp. 20-34.

My own attention was first called to the subject at Cambridge, Mass., in the spring of 1863, and since then this formation has been observed by me almost every year. It is undoubtedly not only very common in our latitudes and soils, but it is also quite an important item in agricultural soil physics.

After a clear cold night (whether windy or not seems to be immaterial) the surface-layer of a moist gravel bed is usually found to be raised up an inch or two by a mass of vertical columns or needles of ice. The lower ends of these do not penetrate the soil below but rest upon what had the previous evening been the next lower layer of gravel. If the wind be very strong the columns are best developed in the sheltered spots. As soon as the sun strikes the raised layer of gravel and warms the tops of the grains they sink a little and then the solar rays perforate slanting holes into the mass of ice crystals. Only once have I seen the corresponding phenomenon of a thin sheet of parallel ice-columns exuding from a vertical crevice in the bark of a tree, many beautiful examples of which are given by Prof. Leconte and Sir John Herschel.

Although dissatisfied with the explanation of this phenomenon, as given by Leconte and others, I was, however, unable to frame a more plausible hypothesis until, lately, when considering the studies made by Mr. Milton Whitney on so-called capillary water, it has seemed to me that the following explanation is plausible:—

During clear spring nights the ground a few inches below the surface retains the warmth of the preceding sunshiny day; by reason of this any moisture that may be there present is preserved as liquid water and works its way upward to the atmosphere either as vapor between the gravel grains, or as a thin film of water enclosing each grain and travelling from one to the next up to the very surface itself by capillary action. The films which would enclose the grains of the uppermost layer of gravel are apt to be quickly evaporated; but the films enclosing the grains immediately below that layer are protected from the wind and from diffusion into the dry air above. No sooner have the upper surfaces of the uppermost grains cooled by radiation below the temperature of their lower sides than there begins a process of conduction of heat upwards through the body of each grain of gravel. Very soon moisture condenses as a liquid film on the cooling lower side of each grain, and soon afterwards on the upper side of the grain of gravel immediately below it, and so on gradually, as night advances, for a considerable distance downwards. When now the uppermost grain has cooled below the freezing point then the next thing that happens is that on its lower surface its thin film of water freezes, and this implies that the water shall freeze last at those points where the upper grain comes in contact with the next lower grains because those points receive a little heat by conduction from below. Thus at these points the frozen films protrude downwards, and the projecting knobs may be considered as minute circles of ice formed in the watery films enclosing the lower grains while the rest of each such films still remains liquid.

Now liquid water has a great surface tension while ice has none; and the watery film enclosing any lower grain will almost instantaneously press in under and lift up the little speck of ice that has formed at the point of contact. The loss of heat by radiation from the upper grain continues steadily, and a steady process of conduction of heat goes on from the water of the lower

film through the ice crystal at the point of contact up to the upper grain. Hence there is a correspondingly steady formation of ice at the points of contact, and a continued renewal of the lifting process takes place until, in the morning, we find the upper grains, and even large pebbles, raised up several inches on the tops of tall columns of ice.

Will not some one devise a miniature repetition of this process in the physical laboratory? Let a small vessel be supported by three rounded metallic knobs resting on surfaces which are covered with thin films of water. The vessel should not be so heavy as to force out the films of water, and the surfaces of contact should not be so large that the circular areas have too large radii. The constricting power of a circular hole in a thin film increases inversely as the radius of the hole. A freezing mixture within the vessel should by conduction send down enough cold to produce ice at the points of support and yet not enough to rapidly freeze any large portion of the film of water. The success of the experiment and of the natural formation of tall columns of ice must depend upon the radii of the frozen circular films at the point of contact and on the rate at which the heat that is absorbed from the lower film, is conducted through the ice and lost by radiation. The delicate adjustment of conditions that will bring this about makes this formation a very interesting physical problem.

When the outer air is frosty, while the sap is pressing up the body of the tree, a thin film of moisture may possibly be supplied from within as fast as the outer film at the surface of a crack may be frozen and lifted, and may thus form the exudations from the trees described by Dr. Leconte and also observed by myself and others.

WASHINGTON, Jan. 23, 1893.

THE DIURNAL VARIATIONS OF BAROMETRIC PRESSURE.

CURTIS J. LYONS.

IT is probably more than a century since the phenomenon of the daily rising and falling of the barometric column was first noticed and commented upon by meteorologists. With the

present activity of scientific research and the stupendous accumulation of records in this particular line, the subject cannot fail of receiving renewed attention, as is evinced by the appearance of Bulletin No. 6 of the United States Weather Bureau, with the same title as that of the present article.

Strange to say, under the system of observation inaugurated by the Smithsonian Institution, — and the writer would speak from the personal experience of many years ago, — this phenomenon was very likely to escape the notice of any ordinary observer. This would especially be the case in those latitudes where the general changes of pressure are so great and sudden as to quite eclipse the daily variation. But by adopting hours of observation corresponding to the average times of maxima and minima, — and these are the best hours for eye observations in any case, — and especially by working at a tropical mid-ocean station, the great facts pertaining to it stand out in bold relief, even to the observer denied the privilege of a barograph. Ten years of careful study encouraged the writer to put forth a few statements and suggestions on the subject. The valuable tabular and graphic records of the observatory at Manila, in the Philippine Islands, have also placed the present writer, as well as the weather fraternity generally, under great obligations to the patient Jesuit Fathers of that station, also intra-marine in its position.

As is well known, the daily variation in the tropics is exceedingly regular, more so, indeed, than the local climatic conditions. No matter what the weather may be, under sunshine or clouds, whether calm or windy, rainy or dry, dew-point low, or dew-point high, after eliminating the general movement, the remaining variation is always there. At Honolulu, the average amplitude for the year is 0.07 in., varying slightly from 0.055 in June and July to 0.085 in December and January. It seems to differ slightly from year to year, probably varying from 0.065 to 0.075. The only exception to the apparent lack of influence of local weather upon the range of this variation is in violent northers, when it is as great as 0.10 or 0.12, once being as high as 0.14, but this is probably only local for this side of the island. Such winds generally blow most severely in the afternoon, causing a partial vacuum on the lee side of the mountains, as pointed out by myself in a previous communication to the

JOURNAL.* This happening at the same time as the minimum pressure, of course increases the amplitude.

The following table of the observed barometer heights for March, 1892, at Honolulu, will indicate the regularity of the daily variation. The heights are all corrected and the daily amplitude, as will be seen, is derived by subtracting the minimum of each day from the two maxima, in order to allow for the general movement of the atmospheric pressure. The real amplitude for the month, however, is the difference of the means of 9 A. M. and 3 P. M. :—

DATE.	BAROMETER.			
	9 A. M.	3 P. M.	9 P. M.	Daily Amplitude.
1	30.17	30.09	30.12	.055
2	30.14	30.06	30.13	.075
3	30.13	30.03	30.10	.085
4	30.11	30.02	30.07	.070
5	30.06	29.97	30.04	.080
6	30.01	29.95	30.02	.065
7	30.01	29.93	29.98	.065
8	30.01	29.94	30.02	.075
9	30.05	29.96	30.05	.090
10	30.03	29.98	30.05	.060
11	30.08	30.05	30.11	.045
12	30.12	30.08	30.12	.040
13	30.14	30.05	30.12	.080
14	30.13	30.05	30.12	.075
15	30.16	30.09	30.16	.070
16	30.17	30.07	30.14	.085
17	30.14	30.04	30.10	.080
18	30.09	30.03	30.09	.060
19	30.11	30.04	30.13	.080
20	30.14	30.07	30.17	.085
21	30.19	30.12	30.19	.070
22	30.21	30.13	30.19	.070
23	30.20	30.13	30.20	.070
24	30.18	30.09	30.19	.095
25	30.19	30.10	30.18	.085
26	30.17	30.10	30.17	.070
27	30.20	30.15	30.23	.065
28	30.23	30.17	30.24	.065
29	30.22	30.13	30.20	.080
30	30.17	30.13	30.19	.050
31	30.19	30.14	30.23	.070
	30.134	30.061	30.130	.073

* Vol. IX., 463-464.

First assigning a probable cause of this daily change in pressure, and then bringing facts in corroboration of the theory, I will proceed as follows: As the influence of the morning sun moves on westward over the earth's surface, the atmosphere is warmed up, the heat increasing till shortly after noon, and the *lower strata* of the atmosphere receiving the greatest increase of temperature. Expansion must necessarily take place, greatest in force in the lower strata, and acting, therefore, not only upward, as we are apt to imagine, but laterally, and especially to the front. That is to say, it is a vast wave of increasing heat driving before it a wave of pressure resulting from the expansion caused by that heat, but too rapid in its advance to cause any appreciable changes in the regular wind currents that prevail. This pressure is most sensible at a distance of from one to two thousand miles in front of the diurnal heat-wave. It stands to reason that this distance would be less were the heat area less, and also if its velocity of advance were less. This lateral pressure it is that causes the barometer to rise to a maximum at a period about half way between local sunrise and the local maximum of temperature.

The mercury then returns to its normal height, but while so returning begins to feel the effect of the cold of the evening which also approaches from the eastward. On the same principle that the advancing heat-wave raises the pressure, the advancing diurnal cold wave, by contraction of its own area of atmosphere, produces a partial vacuum in front of itself; and of course the barometer falls to a minimum in the afternoon of a meridional zone of from one to two thousand miles to the westward of the like zone where the temperature has fallen to the night level.

The law may be stated thus: An advancing area which is increasing in the temperature of its lower strata will cause a high barometer area in front of itself, at a distance from itself proportioned to its size, its rapidity of motion, and the rapidity of increase of temperature.

An advancing area which is diminishing in the temperature of its lower strata, will cause a low area in front of it, governed by the same laws as govern the extent of the high area as stated above.

Before proceeding to the consideration of the night maximum

and minimum, I will give one or two points that bear upon the above explanation :—

First. The phenomena of a solar eclipse, as recorded from the most careful observations of Prof. Winslow Upton, who was associated with Messrs. Holden and Preston in the study of the solar eclipse of 1883, at Caroline Island, a mid-ocean station near the equator, presenting rare opportunities in this field of research, from the extreme regularity of the daily meteorological conditions. These observations are published in the *Memoirs of the National Academy of Sciences*, Vol. II. In this eclipse, and of course in others, the approach of the shadowed, and therefore cooled, portion of the earth's surface resembled on a small scale the approach of the nightly darkened area of atmosphere.

There appears on the carefully plotted curve of pressure in the above-mentioned report a fall of barometer preceding by about twenty minutes the fall in temperature; then a rise of the barometer preceding in like manner the rise in temperature, and by about the same period, and continuing to rise to a point slightly above the normal, and then falling to the normal curve for the day. This normal curve, of course, had been established by previous days' records which had been made with great care. These facts certainly appear to corroborate, if not actually to prove, the theory of the above explanation of the diurnal wave.

Second. Another very important argument for the lateral expansive force theory is the fact of the rapid diminution in the amplitude of the variation as we ascend to great heights.

On the summit of Mauna Kea, 13,820 feet above the sea level, it is less than one half of its amount at Honolulu. There is not good evidence in this case to prove that there is any material difference in the hours of maxima and minima from those below. Very careful observations were made at Waiau, in the immediate neighborhood of the above-mentioned station, about five hundred feet lower, in July, 1892, by Messrs. Alexander and Preston of the Hawaiian and United States Surveys, and which will doubtless appear in the reports of the latter gentleman to the United States Coast and Geodetic Survey. This difference in amplitude, it should be remarked, is much greater proportionally than the difference in weight of the superincumbent

atmosphere, which would of course cause a difference in any case. It has also been observed on these Islands with like results at other stations.

Third. The variation in the time of maximum, from summer to winter, is even greater, in this latitude, than the variation in time of sunrise, which fact would agree with the theory that the cause is far off, which theory would involve the assumption that a component of said cause is distant and in more northern regions, where the summer sun rises much earlier than here. So it is also with the minimum. The summer maximum is at 8 A. M.; in winter it is at 10, or even later; the afternoon summer minimum is at 4.30; the winter minimum is about 2.30, thus corresponding with the apparent solar movements. The winter amplitude is greatest because the temperature daily range is greatest, both in the tropics and in extra-tropic regions; summer brings less amplitude of temperature variation and less of barometric.

The regularity of amplitude, taking single days one after another (as shown on page 527), indicates a cause far from local, and moreover a simple cause, and not one combined of several nearly equal, but somewhat variable, forces. There may be smaller components, and I would indicate as such the wave action to be mentioned below, and the rise in the dew-point from sunrise to 9 A. M., remarking *per contra* that there is no appreciable fall in the dew-point from 9 to 3.

The night phenomena remain to be explained. The evening maximum is, I take it, a reactionary wave from the afternoon minimum. In support of this theory I bring the fact, that in the mid-summer time, when the morning maximum is early and the afternoon minimum late, the evening maximum is very late, viz., at 11 P. M. or later. It will be seen from the times given above that eight hours have intervened between the maximum and minimum of the daytime, and as a consequence the reactionary rising wave lasts as long as seven hours, giving the time of 11 P. M. mentioned above. In mid-winter the contrary takes place, the evening maximum coming as early as 8 P. M., the daytime interval having been less than six hours. These facts would appear to favor the theory as given. Moreover the night maximum is the less of the two, as might be expected. Why, then, it will be asked, does not a late morning minimum cor-

respond with a late evening maximum? Because the morning rise of pressure has already begun, and crowds back the minimum to an earlier hour, much as an incoming solar tide of the sea throws back the lowest point of an outgoing lunar tide. We cannot, it should be remarked here, accept any explanation of the atmospheric tides, corresponding to that of the marine tides, viz., of a double daily tide resulting from gravitational balancing on opposite sides of the earth.

If, then, an approaching extended cold area causes far ahead of it a corresponding low area of atmospheric pressure, as seems probable, it is easy to see how we may perhaps feel our way to the solution of the problem of the formation and causes of the cyclonic storms of the Mississippi Valley, and also of other temperate zone regions. I say perhaps, for certainly there is a difference between the phenomena of an advancing mass of air, with its own temperature, and those of an advancing area of either heating or cooling influence from without. Still, may it not be possible that a vast mass, or extent, of atmosphere, say in northern Manitoba and the neighboring country, having its normal cold temperature for that latitude, but deflected from its normal course of progression which would be to the eastward, and drawn southeasterly by causes which we will not now seek to specify, but which may be as far south as the Gulf of Mexico, — may it not be possible, I say, that being, as it is, a "cold wave," it might produce the phenomena of a "low area" preceding it, causing this low pressure in the central United States? The easterly and southeasterly surface winds, so well known in their relation to this low area, would be overlapped by the upper-atmosphere portion of the cold wave, that like a half wedge precedes in progression the lower portion retarded by the friction of the earth's surface, and hence the phenomena of the storm "working downwards," which are noticed even in these low latitudes.

But all this properly belongs to a distinct paper on the subject, in the first place, and in the second place is related to regions pretty thoroughly exploited by others than the writer. It is chiefly for the purpose of bringing out more fully the importance of the main question, that this further application of the theory proposed has been here added.

RECENT FOREIGN STUDIES OF THUNDERSTORMS:

I. GREAT BRITAIN.

R. DE C. WARD.

IN this JOURNAL, Vol. II., pages 489-499, Vol. III., pages 40-48, 69-79, Prof. W. M. Davis gave a summary of the most important foreign contributions to the study of thunderstorms, taking up the subject by countries, and including in his review France, Italy, Bavaria, Central Germany, Switzerland, Russia, India, Norway, and Great Britain, with mention of special examples in the Persian Gulf and Uruguay, in the order named. The present writer has spent a considerable share of time during the past two years on an investigation of the thunderstorms of New England, some of the results of which have already been published in this JOURNAL,* and in order to gain a comprehensive view of the whole subject he has found it necessary to become familiar with similar work in other countries. Thinking that a brief summary of the most important recent foreign studies of thunderstorms may be useful as well as interesting to the readers of this JOURNAL, he presents the following as the first of a series of papers on the subject.

The plan of the present and of the succeeding papers is, briefly, to take up the matter where Prof. Davis left it, and to bring the review down to date, as far as possible. In doing this use has been made of the Signal Service *Bibliography of Meteorology*, Part IV., "Storms," which gives a catalogue of the printed literature of the subject to the close of 1889. For the literature since that year the writer has looked through the meteorological journals and the various publications of the different weather services, meteorological societies, observatories, etc., and has tried to give as full a list as possible of what has been written from 1890 to the close of 1892. That the list is not complete the writer is well aware, but it is as good a one as the time and the materials at his disposal would allow, and includes, it is believed, at any rate all the most important works. No attempt is made to summarize every article or pamphlet, but only to re-

* Vol. IX., pages 21-28, 211-215.

view the most noteworthy, which are of more than local interest, and to give each writer's own conclusions.

When Prof. Davis gave his summary,* in 1886, of the work done in Great Britain, he had reason to say that very little had been accomplished in the systematic study of thunderstorms in that country; but since that time there has been a decided change. The first system of collecting data concerning English thunderstorms was started in the year 1856 by Mr. G. J. Symons, who carried on his work, with the assistance of volunteer observers, for over thirty years. During this time he collected a vast amount of valuable material, but his early efforts to bring the subject into the prominence it deserved were unsuccessful. His first paper, "On the Thunderstorms of 1857," was read at a meeting of the British Meteorological Society in 1858, but not even the title of the paper was recorded in the publication of that society. His second paper, read before the British Association in 1859, had only its title printed in the report of the meeting. The third paper, read before the British Association in 1860, was given twenty-seven lines in the report of that year's meeting. Mr. Symons has written several articles,† during the past few years, giving some of the results of his investigations, which present carefully prepared statistics of the intensity of the storms, the extent and nature of the damage done to life and property, etc.

In 1888, under the initiative of the Hon. Ralph Abercromby, with some support from the Royal Society, the Royal Meteorological Society started a systematic thunderstorm investigation, similar to that undertaken by the New England Meteorological Society in this country in 1885-1887. In that year a circular was issued by the Royal Meteorological Society in which it was stated that the objects it was hoped to attain in this investigation were: "I. A knowledge of the nature and causes of the different kinds of thunderstorms; attention having been called specially to the subject by the great loss of life and property during the past summer. II. A discovery of the localities where hail and thunder are most frequent and destructive. III.

* *American Meteorological Journal*, III., 1886, 71-74.

† Symons's *Monthly Meteorological Magazine*, XIX., 1884, 101-108, 117-122, 135-140, 149-159; XXI., 1886, 133-137; XXII., 1887, 132-134; XXIII., 1888, 116-121.

If possible, to obtain an increased power of forecasting hail and thunder, whereby it is hoped that, eventually, damage to persons, stock, and property may be lessened." There were three classes of observers, the first two needing no instruments, while the third class took note of the shape and motions of the clouds, barometric changes, and of the dry and wet bulb thermometers, in addition to the simple record of rain beginning, first and loudest thunder, etc., required of the first two classes.

The Thunderstorm Committee of the Society, in the year when it undertook this work, asked Mr. Symons to publish his paper on the "Results of an Investigation of the Phenomena of English Thunderstorms during the Years 1857-1859,"* which he had, as above stated, read before the British Association, in 1860, but which had not at that time been published.

This paper is largely statistical. It appears that, taking an average of the three years, thunderstorms were reported on one hundred and twenty-one days of the year; the month of most frequent reports being June. Another report,† by William Marriott, F. R. Met. Soc., deals with the results worked up for the Thunderstorm Committee of the Royal Meteorological Society on the "Distribution of Thunderstorms over England and Wales, 1871-1887," that is, the years preceding those during which the society took up the investigation. The data used were obtained from Symons's "British Rainfall," the Registrar-General's "Quarterly Returns of Births and Deaths," and from the records of the Royal Meteorological Society. All reports of thunderstorms, thunder without lightning, lightning without thunder, and sheet or distant lightning have been grouped together as "thunderstorms." The stations are arranged in geographical districts corresponding to those adopted by the Registrar-General of births and deaths. It appears from the tabulated results that the years of greatest frequency were 1880, 1882, 1884, and 1872, and the years of least frequency 1887, 1874, 1879, and 1871. The average yearly number of thunderstorms in each district was about thirty-nine. July was the month of most frequent thunderstorms except in Wales, where it was August; February and December had the least. The greatest number of winter thunderstorms occurred in the southwestern, southern,

* Quart. J. R. Met. Soc., XV., 1889, 1-13.

† Quart. J. R. Met. Soc., XVI., 1890, 1-12.

and northern divisions. Of these the southwestern, Cornwall, Devon, etc., which are largely surrounded by water, had the maximum number. This confirms the results obtained elsewhere that winter thunderstorms are shore or marine phenomena.

The first report on the recent observations of the Royal Meteorological Society was made by Mr. Marriott,* in 1891, and as this is an important contribution to the subject it is given considerable space here. The original plan was to undertake a systematic investigation of these storms in the southeast of England, but the field was later extended to include the other parts of the country also. It was in charge of a Thunderstorm Committee appointed by the Council of the Royal Meteorological Society. Circulars were sent to all the rainfall observers in the southeast of England, and to the Fellows of the Society. In all, two hundred and twenty-three persons volunteered for the work, ninety-two in the southeast of England, and one hundred and thirty-one in other parts of the country. The blanks were arranged for three classes of observers, A, B, and C. Class A was to note the intensity of the storm, the times of the first, last, and loudest thunder; first, last, and brightest lightning; first, heaviest, and last rain, and hail. Class B was to note, in addition, the direction and force of the wind before, during, and after the storm. Class C had further to note the least number of seconds between the lightning and thunder; other electrical phenomena; form, color, and description of flashes; form of clouds; pressure; temperature (wet and dry bulb); direction and force of wind, and direction of clouds. The method of discussion is as follows: the times of first thunder, of sheet lightning, and of hail were plotted on maps and entered in tables of hourly frequency. Next the position of places was noted where any damage by lightning was reported, different symbols being employed to indicate loss of human life, loss of animal life, and structural damage. The stations were arranged according to the divisions adopted by the Registrar-General of births and deaths. In 1888, June had twenty days of thunderstorms, July had twenty-six, and August had eighteen, the total for the year being one hundred and thirteen days. In 1889, May had twenty-four days of thunderstorms, April and July nine-

* Quart. J. R. Met. Soc., XVIII., 1892, 23-39.

teen, August fifteen, and June fourteen, the total for the year being one hundred and twenty-three days. In 1888, thirty-two days brought damage by lightning; in 1889, thirty-eight. The hours of greatest frequency of thunderstorms were noon to 4 P. M.; the hours of least frequency 1 A. M. to 7 A. M. Thunderstorms at night occurred mostly in counties near the southern and southwestern sea coast. In plotting the paths and rate of travel, the following points were noted: times of first and last thunder, the times of commencement and ending of the rain, the occurrence of hail, the direction and force of the wind before, during, and after the storm, and the changes in temperature of the air. With regard to the path and rate of travel of thunderstorms, Mr. Marriott speaks as follows: "Thunderstorms appear to travel at an average rate of eighteen miles an hour in ill-defined low barometric pressure systems; but at a higher rate in squally conditions. I am inclined . . . to think that individual thunderstorms do not travel more than twenty miles. Thunderstorms evidently take the path of least resistance, and consequently are most frequent on flat and low ground." The connection of thunderstorms with the larger cyclonic storms is clearly brought out in this study, as the former "usually occurred when the isobars showed large areas of ill-defined low pressure, or when there was a lane or trough of low pressure between higher pressure on either side." The thunderstorms did not appear to be influenced by the height of the barometer, as they occurred when the pressure was 30.40, and also when it was below 29 inches.

In order to study out the conditions of thunderstorm generation more minutely, charts were prepared for 9 A. M. and 9 P. M. for each day of June, 1888, on which were drawn isobars for every two hundredths of an inch, direction and force of the wind, temperature, relative humidity, and vapor tension. An examination of these detailed charts showed that the districts where thunderstorms occurred were often covered by small secondary cyclones, with regular spiral wind circulation; these secondaries not appearing on the charts having isobars drawn for every ten hundredths of an inch only. This leads Mr. Marriott to the conclusion that thunderstorm formations appear to be small atmospheric whirls, in all respects like ordinary cyclones. There are further what are called "line" thunderstorms, one of which

crossed England from south to north for over four hundred miles, and thunderstorms accompanying large barometric depressions, the latter occurring usually in winter, being frequently associated with squalls, and being usually in the southeast quadrant of the depression. Mr. Marriott believes that thunderstorms are whirls varying from one mile to ten miles or more in diameter, and as the clouds are of no very great altitude, he thinks the whirl is confined to a lower stratum of air, the average storm not extending beyond 4,000 or 5,000 feet above the earth's surface.

As a help to other persons who may desire to look up this subject, a bibliography of the literature on the thunderstorms of Great Britain since the close of 1889 is presented at the end of the article.

Of these articles we have already reviewed I and II. In 2, the author has taken the records of the Kew Observatory for ten years, and noted the dates when actual thunderstorms passed over the observatory, with the changes in temperature which resulted. He finds that the general effect of a thunderstorm is to reduce the mean temperature of the air, on the day on which the thunderstorm occurs, 0.6° , the mean temperature of the two days following, 1.7° , and that of the three days following, 1.5° . In 5, Mr. R. H. Scott, the present Secretary to the Meteorological Council, divides the thunderstorms into two groups, — *heat* thunderstorms, which are the continental and summer type, and *cyclonic* thunderstorms, which occur mostly in autumn and in winter, and over the ocean or over islands. The energy of these storms is materially modified by the dampness of the climate, hence the comparative immunity from them in the British Islands. Certain districts appear to be more liable to thunderstorms than others, and hail appears to do more damage in Huntingdonshire and the neighboring counties than in other parts of England. "As regards forecasting thunderstorms," Mr. Scott says, "this can be done in a general sort of way, but it is not practicable to predict which valleys, or parishes, or even counties, will be visited. When the daily weather charts are drawn, if we find that there is an unevenness in the isobaric lines, — that is, if these are wavy or bulged out irregularly, — we know that thunderstorms are likely to burst somewhere or other over the country, but that is all we can say. Forecasting these

storms is . . . always an uncertain and a thankless task, for local success is rarely attained." In describing the appearance and movement of the thunder-clouds, Mr. Scott says: "It is a general observation that no electrical explosion or downfall of rain ever takes place from a cloud unless streamers of cirrus, emanating from its upper surface, are visible when the cloud is looked at sideways from a distance."

Mr. R. C. Mossman, in 6, gives an interesting account of the thunderstorms at Ben Nevis Observatory, the mountain observatory of Great Britain. During the six years from 1883 to 1889, fifty-six thunderstorms were observed at the observatory, this including cases of thunder only and of lightning only. The average number of days per annum on which the phenomena were observed was six. The thunderstorms on Ben Nevis are essentially autumn and winter phenomena. At Fort William, a town at the base of Ben Nevis, the winter maximum is more strongly marked than on the mountain, and the summer thunderstorms are also much more frequent, thus showing that a large number of these storms do not reach to the top of the mountain, and are, therefore, phenomena of the lower atmosphere. All the summer thunderstorms occurred when the sun was above the horizon, while thirty-two out of thirty-seven cases of autumn and winter thunderstorms occurred when the sun was below the horizon. The winter thunderstorms occur when there is low pressure to the west or northwest, and high pressure over the Iberian Peninsula. They are invariably in the southeast quadrant of a depression. The summer thunderstorms, on the other hand, are apparently not associated with any special distribution of pressure. The rapid falls in temperature which characterize low-level thunderstorms do not take place at the summit of Ben Nevis. On comparing the periods of maximum frequency of thunderstorms on Ben Nevis with those on the Sæntis, the Rigi, and the Great St. Bernard, it is seen that the last named stations have their thunderstorms nearly always in summer, while, as just stated, Ben Nevis has its greatest frequency in winter and at night.

Papers numbered 3, 4, 7, 8, 9, 10, and 12 are short notes on different storms, and present no special features that need review here.

Mention should be made, further, of two text-books, those of

Mr. R. H. Scott, "Elementary Meteorology," published in 1882, and of Hon. Ralph Abercromby, "Weather," which appeared in 1887. Mr. Scott adopts Mohn's classification of thunderstorms as *heat* thunderstorms and as *cyclonic* thunderstorms. The former, he says, are predominant in summer and in hot climates; the latter are characteristic of the Atlantic coast of Great Britain, and accompany cyclonic disturbances, being commoner in winter. In the second text-book, that of Abercromby, thunderstorms are classified as thunder-squalls, line thunderstorms, and thunderstorms in secondary cyclonic depressions. The first class, thunder-squalls, are very common on the west and northwest coasts of Great Britain in winter. Line thunderstorms occur usually in V-shaped depressions, or troughs, and sweep broadside across the country in long narrow bands. The wind sequence in these cases is usually a light southeast wind in front of the V; just before and at the beginning of the rain a violent squall-wind from the west, and lastly a light southwest wind in the rear. Line thunderstorms also occur with no apparent connection with the trough of a cyclone or of a V-depression, and also move broadside across the country. Lastly, thunderstorms with secondaries, which are more complicated than simple squalls, and are different in many ways from line thunderstorms. These are much commoner in England than line thunderstorms, and are sure to occur whenever a secondary depression is seen on the charts in summer. The features of this class are calm and sultry weather before the storm, and a limited rotation of the surface wind during its progress.

From this brief review of the principal recent contributions to the subject of thunderstorms in Great Britain we learn that this class of storms is in that country usually associated with a trough-shaped cyclonic depression or with a secondary, and that the winter thunderstorms are distinctly nocturnal and sea coast phenomena.

The relations of the thunderstorms to the larger movements of the atmosphere, and their effects in passing over the observers, have been carefully noted and duly discussed; but the mechanism of the storms and the recognition of their different parts have been largely neglected. Mr. Symons in his work made no attempt to do more than give statistics of intensity

and of the nature and extent of the damage done to life and property. Mr. Marriott has gone further into the subject, as we have seen, and has brought out some valuable results as to the conditions of occurrence, frequency, and general nature of thunderstorms. The value of his results is, however, considerably diminished by the fact that he adopts such artificial divisions of the country in his work, a feature that has already received English criticism, and further by the fact that when lightning was seen at a station it was considered as a thunderstorm at that station. Lightning can be seen from thunderstorms many miles distant, and to call lightning alone a thunderstorm is manifestly wrong and gives wrong averages, if we are trying to find out the numbers of actual thunderstorms. So, also, the results at Ben Nevis, in the discussion of which Mr. Mossman included under thunderstorms lightning only and thunder only, cannot be considered very exact. The comparison of the storms on Ben Nevis and at Fort William leads Mr. Mossman to the conclusion that a large number of thunderstorms do not reach to the top of the mountain which are noted at the base station. The question naturally arises, What is a thunderstorm? Is it the rain alone, or the lightning alone, or the thunder alone, or two or all of these together? This opens up an interesting field for discussion, which, however, it is not our present plan to enter upon. It may be stated in conclusion that the recent work on the thunderstorms of Great Britain, in spite of some imperfections, has helped much towards a better understanding of this class of storms, and is a valuable contribution to the subject.

1. MARRIOTT, W. *Distribution of Thunderstorms over England and Wales, 1871-1887.* (With discussion.) Quart. J. R. Met. Soc., Lond., XVI., 1890, 1-12.
2. WHIPPLE, G. M. *On the Change of Mean Daily Temperature which accompanies Thunderstorms in Southern England.* (With discussion.) Quart. J. R. Met. Soc., Lond., XVI., 1890, 12-15.
3. CLARK, J. E. *Thunderstorm and Whirlwind at York, March 8, 1890.* (With discussion.) Quart. J. R. Met. Soc., Lond., XVI., 1890, 169-178.
4. SLATTER, J. *Thunderstorm, August 2.* Symons's Met. Mag., Lond., XXV., 1890, 120.
5. SCOTT, R. H. *Thunderstorms.* Longman's Mag., Lond., XVI., 1890, 192-202. (Nature, Lond., XLII., 160.)
6. MOSSMAN, R. C. *Thunderstorms at Ben Nevis Observatory.* Journ. Scot. Met. Soc., Edinb. and Lond., Third Series, No. VII., 1890, 33-38.
7. BIDL, H. *Curious Effect of a Thunderstorm at Playford, in Suffolk.* Nature, Lond., XLII., 1890, 36.

8. WAGSTAFFE, W. W. *The Thunderstorms of August 3 and 4, 1891.* Symons's Met. Mag., Lond., XXVI., 1891, 106.
9. MACE, J. E. Do., Ibid.
10. (SYMONS, G. J.) *Thunderstorm and Cloudburst near Duffield, July 3.* Symons's Met. Mag., Lond., XXVII., 1892, 82-85.
11. MARRIOTT, W. *Report on the Thunderstorms of 1888 and 1889.* (With discussion.) Quart. J. R. Met. Soc., Lond., XVIII., 1892, 23-39.
12. DOD, C. W. *Thunderstorm and Fog, April 17 and 18, 1892, at Malpas, Cheshire.* Quart. J. R. Met. Soc., Lond., XVIII., 1892, 148.

HARVARD COLLEGE, March 1, 1893.

THE CHINOOK WIND.

HOWARD M. BALLOU.

THE extreme severity of the winters in certain parts of our northwestern states, among the Rocky Mountains and along their eastern base, is much tempered by the prevalence of a mild westerly wind, locally called the chinook. Its name is derived from that of the tribe of Chinook Indians, living near Puget's Sound. It is said first to have been applied by the early Hudson Bay trappers and voyageurs, who, meeting the wind while travelling towards the Pacific coast, and finding it particularly strong and warm as they approached the lands of this particular tribe, called it the chinook wind.

It is described as a soft, balmy wind, varying in velocity from a gentle breeze to a steady gale. Though its temperature rarely exceeds 50° F., yet coming as it does when one is accustomed to a low temperature, it seems warm by contrast with the preceding weather. The thermometer often rises from below the zero point to 40° or 45° in a few hours, and the maximum temperatures of the winter months in the Rocky Mountain region nearly always are coincident with the occurrence of a chinook.

The sky is usually clear while the warm wind blows, though observers often note a few leaden-colored clouds of a kind seen only during the chinook. These clouds are described as pancake shaped, with peculiarly smooth rounded edges, and stand apparently motionless, high above the mountain ranges.

The continuance of a chinook is as uncertain as its coming. It may last a few hours or for several days. With a change of wind the temperature falls rapidly, and winter weather once more sets in.

The chinook wind possesses to a remarkable degree the power of melting snow, for it is not only warm, but appears to be dry. Although a foot or more of snow may lie on the ground at the beginning of a chinook, it disappears within a very few hours, often seeming rather to evaporate than to melt. For this reason the chinook is most welcome to the cattlemen on the plains of Montana and Wyoming. In fact, without it, stock raising would be almost impossible, as the dried grasses of the plains, on which the cattle subsist, would otherwise be buried the greater part of the winter.

To a few, however, this wind, instead of being hailed with delight as a break in the cold of the winter, is a source of much discomfort. A correspondent writes from Colorado that "the nervous effects of this wind are as distinctive as the neuralgic character of a Boston sea turn. There is a restlessness which cannot be accounted for as due simply to the unusual warmth. Many nervous people feel prostrated by it, and tremble and fidget incessantly during a chinook. The faster the wind, the worse these symptoms are. Some people, ordinarily sound sleepers, lie awake often a large part of the night during its prevalence. There is always some of this restlessness or nervousness,—that unknown something which people feel, yet can hardly describe, still less scientifically define."

The effect of the chinook on trees, especially those near the foot of the mountains, is far from beneficial, as sometimes, in early spring, under the influence of one of these winds, they are tempted unseasonably to start their sap and to open their leaf buds, only to be nipped in a few days by a cold wave. The forest commissioner of Colorado cites as an example of this that some few years ago broad belts of coniferous timber upon the slopes of the Pikes Peak or "front" range were stricken with something which caused their foliage to wither and turn brown. The trees were at first thought to be dead, but afterwards revived and appeared as sound as ever. From circumstances noted at the time it was supposed that this was occasioned by a chinook, followed by a cold wave.

It is not unnatural that the cause of the unseasonable warmth of the chinook should be popularly ascribed to the Kuro-Siwo, or warm Japanese current of the Pacific Ocean, which, as a part of the general circulation of the Northern Pacific, so favorably

affects the climate of our Pacific coast. Winds from the Pacific would, of course, derive considerable warmth from this warm current, and would also obtain a great deal of moisture; but the warm, dry chinook of the region east of the mountains is quite different from the warm, moisture-laden wind of the western slope.

We may, perhaps, gain assistance by inquiring, do similar winds prevail in any other portion of the globe? If so, have they not similar origins?

In the Eastern Hemisphere, eastern France and central Germany correspond nearly in position to those regions in the Western Hemisphere where the chinook prevails. Their westerly winds pass over the Gulf Stream as those of the Pacific cross the Kuro-Siwo, but no wind corresponding in its properties to the chinook has ever been there reported.

In Switzerland, however, about forty years ago, the attention of meteorologists was called to a peculiar wind in the Alps, which, blowing directly from the tops of snow-clad mountains, possessed, nevertheless, warmth and dryness to a marked degree. It was there called the *foehn*, a name said to be derived from the old Latin name of the wind, *Favonius*.

It was at first thought that the *foehn* originated in the Desert of Sahara, and, blowing across the Mediterranean, high above the earth, finally descended in the neighborhood of the Alps. Certain prominent advocates of this theory even held that the submergence of the desert in recent geological time, by extinguishing the source of this wind, allowed the glaciers to accumulate on the Alps. But it is now known that only a small part of the desert was under water at the time Switzerland was glaciated, so that this ingenious explanation and apparent confirmation of the theory is shown to be wrong.

Moreover it was soon noticed that whenever the *foehn* blew on the northern side of the mountains, a southerly wind also prevailed on the southern side, but instead of being dry, brought more or less rain, and hence was not derived from the arid desert.

Travellers in the Andes * reported a similar wind, there called

* J. Miers, *Travels in Chile and La Plata*, London, 1826, i. 282. Quoted by W. M. Davis, *Amer. Met. Jour.*, iii. 1886-87, 509. N. H. Bishop, *A Thousand Miles Walk Across South America*, Boston, 3d ed., 1874, 239. Quoted by W. M. Davis, *Amer. Met. Jour.*, iii. 1886-87, 507, 508.

the Zonda, blowing on the eastern side of the mountains and thought by them to be of volcanic origin, for in no other way could they account for so warm a wind descending from so cold a region as the snow-clad mountain peaks.

Similar winds were also reported from Persia,* from New Zealand,† and elsewhere, always to leeward of high mountains.

Then the same occurrence was noticed in Greenland,‡ the warm wind being felt on the west coast during the winter months. Here the wind blew directly from the interior plateaus, covered with glaciers and permanent snows, and it was very evident that no source of the warmth could there be found.

Meanwhile, the true cause of the warmth and dryness had been made out by several meteorologists, the eminent American meteorologist, Espy, first correctly stating the physical principles of the process.§ The establishment of the Swiss Meteorological Service, in 1863, had soon furnished valuable data for the study of the foehn, and the fact of its extreme dryness, which had been disputed by some meteorologists, notably Dové, was completely demonstrated. By inspection of the weather maps, its cause was seen to be dependent, not on the general planetary circulation, but on storms, as shown by the intermittent character of the wind, and the correspondence of the positions of the storm centres during the prevalence of the foehn. Helmholtz, in 1865, gave a correct, though not complete, deductive explanation of the cause of the foehn; Hann,|| in 1882, completed the explanation of its origin by a close examination of the facts and conditions of its occurrence.

It was shown that the warmth was due, not to some hot region from which the winds might have blown, but to an entirely local and physical cause, — the compression of the air in descending the mountain sides to lower levels.

* Rev. J. Perkins, a letter quoted by Prof. Coffin in *Winds of the Northern Hemisphere*, 104. Also quoted by Espy, *Fourth Met. Report*, 147.

† Capt. B. Drury, *Meteorology of New Zealand*. First number of *Met. papers*, published by authority of Board of Trade, London, 1857, 71, 73. J. v. Haast, *Geol. of the Prov. of Canterbury and Westland, New Zealand*, Christchurch, 1879, 198, 199. M. O'Brien, a letter quoted by S. Haughton, *Six Lectures on Physical Geography*, Dublin, 1880, 102. Quoted by W. M. Davis, *Amer. Met. Jour.*, iii. 1886-87, 442.

‡ Hoffmeyer, *Le Foehn du Groenland*, Copenhagen, 1877.

§ Espy, *Fourth Meteorological Report*, Washington, 1857, 146, 147, 151.

|| Hann, *Wiener, Akad. Sitzungsber*, 1882, lxxv., 2^o, 416.

When air expands it pushes aside the surrounding air, doing work, and thereby losing some of its own heat; a well-known principle employed in various refrigerating apparatus. Similarly, when air is compressed, work is done upon it and its heat is thereby increased.

From data determined by physical experiment, it has been shown that the amount of heat lost by non-saturated air in ascending, owing to its expansion against the rarer upper air, is at the rate of 1.6° F. for every three hundred feet of ascent. An equal rise in temperature is found when air descends a like distance.

All then that is needed to produce a foehn or chinook, is some arrangement of high and low pressure areas, whereby the air is caused to pass over the mountains, descending on the leeward side.

The average vertical diminution of temperature is at the rate of 1° F. in three hundred feet, so that when air from a great height is quickly brought down to the ground, though ordinarily 1° colder for every three hundred feet than the lower air, yet warming 1.6° in each three hundred feet of descent, it reaches the ground warmer by several degrees than the surrounding air. From this it also follows that the greater the distance through which the air has descended, the greater the difference in temperature. The descent must be rapid to allow little time for loss of heat by radiation or conduction. The first stage of the chinook, then, is this rapid descent of the air from the top of the mountains.

Air from the foot of the windward side of the mountains is now drawn to the top and descends in turn on the other side. Were this air dry when it started to ascend the mountain, cooling on its way up, and warming at an equal rate during its descent, it would reach the same level on the other side no warmer than when it started.

But owing to the moisture present in the ascending air a new element is introduced. The amount of moisture that can exist in the atmosphere decreases very rapidly with a decrease in temperature. So as the air cools in ascending, at first at the rate of 1.6° for each three hundred feet, it soon is no longer able to retain all its moisture. When the dew point is reached, clouds begin to form and rain commences soon after. The latent heat

now given out by the condensation of the water vapor retards the cooling, which continues at a much reduced rate. If the mountain range is high, much of the moisture in the air is precipitated before the summit is reached.

Descending on the other side, the reverse process occurs. The air warms and its capacity for moisture being thereby increased, soon dissolves the clouds present. Thus the clouds can advance no further than just over the mountain top, and remain there apparently stationary during the continuance of the wind. Although the leeward edge is continually evaporated, the whole mass is constantly re-enforced by cloud particles from the rear.

Until the moisture in the air is entirely evaporated, the warming during descent is retarded by the loss of heat necessary to evaporate the water particles. But as only a little moisture remains, the greater part having fallen as rain, this point is soon reached. Thereafter the warming is at the rate of 1.6° F. for each three hundred feet of descent. This warming at the maximum rate evidently continues for a longer time than the cooling at the same rate during the ascent. The air, therefore, reaches the ground warmer and dryer than when it started.

Examples of foehn winds should be found to leeward of all good-sized mountain ranges, though unfortunately they have as yet been but little studied.

In the regions where they are known to occur a systematic study of their origin, occurrence, and characteristics would be of the greatest service to meteorologists, as the data at present obtainable is very insufficient for their purposes.

In the west, the term chinook does not seem popularly to be applied to winds of this foehn-like origin alone, but to any warm westerly wind. Some of these may, perhaps, originate in the Pacific Ocean, and give basis to the popular belief as to their origin. The true test of a foehn-like chinook ought to be its comparative dryness, for, as explained, the chinook is constantly growing warmer, and so its capacity for evaporating water increases very rapidly, and it is constantly able to absorb more and more moisture. So its per cent of relative humidity ought to be low. Unfortunately, no special record seems to have been kept at any station of the humidity during the prevalence of a chinook.

Comparatively little has yet been written concerning the

chinook. The following short list comprises all the articles I have been able to find. It will be noticed that all the important articles, without exception, have appeared in the AMERICAN METEOROLOGICAL JOURNAL, either originally or by reprinting:—

JAS. P. ESPY, "Fourth Meteorological Report," 1857, pp. 146, 147, 151.

GEO. M. DAWSON, "Report of Progress, Geological Survey of Canada," 1879-80, p. 77 B. Quoted by him, *Science*, vii., 1886, p. 33. Quoted by C. C. McCaul, *AMER. MET. JOUR.*, v., 1888-89, p. 151.

L. A. SHERMAN, "A Theory of the Chinook," *AMER. MET. JOUR.*, ii., 1885-86, pp. 18-22.

GEO. M. DAWSON, "Chinook Winds," *Science*, vii., 1886, p. 33.

W. M. DAVIS, "Chinook Winds," *Science*, vii., 1886, p. 55.

W. M. DAVIS, "Mountain Meteorology," Part II. *Appalachia*, iv., 1886, pp. 336-348. Reprinted in *AMER. MET. JOUR.*, iv., 1887-88, pp. 182-191, 224-227.

M. W. HARRINGTON, "The Chinook Wind," *AMER. MET. JOUR.*, iii., 1886-87, pp. 330-339, 467-475, 516-523.

H. A. HAZEN, "Chinook Winds," *Monthly Weather Review*, Jan. 1888, p. 19. Reprinted in *AMER. MET. JOUR.*, v., 1888-89, pp. 186-188.

E. INGERSOLL, "The Climate of the Canadian West," *Canadian Record of Science*, iii., April, 1888, p. 91. Quoted by C. C. McCaul, *AMER. MET. JOUR.*, v., 1888-89, pp. 149, 152.

C. C. MCCAUL, "South Alberta and the Climatic Effects of the Chinook Wind," *AMER. MET. JOUR.*, v., 1888-89, pp. 145-159, 362-369.

THE NORTH ATLANTIC HURRICANE OF DEC. 22, 1892.

EVERETT HAYDEN.

THE accompanying map, from the "Pilot Chart" of the North Atlantic Ocean for February, illustrates, far more graphically than any mere description can do, the great size and severity of the hurricane of Dec. 22. It is probably not too great an estimate to say that the area embraced within the outermost sweep of its cyclonic winds was fully *four million square miles*. In other words, if such a storm were central over the United States its northwesterly gales would be felt all along the Pacific coast, its westerly and southwesterly gales would be raging in the Gulf of Mexico, southeasterly along our Atlantic coast, and northeasterly over the Gulf of St. Lawrence and the Great Lakes.

The following quotations from the "Pilot Chart" give a brief but fairly complete account of this great storm, which, judging by the time of its occurrence, its severity and its persistency must be held accountable in some degree for the succeeding

very cold weather in North America and Europe. The "Pilot Chart" says:—

The storm off Hatteras on Dec. 20 moved rapidly along a track about E. N. E., and became central on the 22d about lat. $46^{\circ} 30' N.$, lon. $36^{\circ} 15' W.$, with greatly increased energy, as illustrated by the small weather map herewith. At this time the isobar of 29.70 extended from Nova Scotia to a point 150 miles south of the Azores, to Portugal, to Ireland, to the southern part of Greenland, and back to the mouth of the St. Lawrence River; throughout a great part of this region it was blowing a full hurricane, and at the centre the corrected barometric pressure was as low as 27.75. The storm recurved toward Newfoundland on the 23d and 24th, and back again to the N. E. on the 25th, thus practically occupying the entire northern part of the Atlantic for fully four days, and leaving a secondary over Newfoundland that caused heavy weather for three days more.

Each little arrow on the chart is the Greenwich noon observation made on board a certain vessel on that day, the symbol representing the wind and weather reported. The isobars, or lines of equal barometric pressure, are based upon the most reliable barometer readings at hand, and they represent the corrected pressure throughout the region charted. In work of this kind mercurial barometers are far more reliable than aneroids, and these isobars are based almost entirely upon readings of mercurial barometers whose errors (as shown by regular comparisons with standards) are constant, or very nearly so.

A specially interesting feature of this storm is the fact that it has furnished some of the lowest reliable barometer readings ever reported from the North Atlantic. Of these the lowest (mercurial) is 27.75, from the Netherlands-American steamer "Werkendam," Captain Bakker. The track of this vessel is shown; the following is a brief summary of the report by Fourth Officer Roggeveen:—

From noon, Dec. 22, lat. $50^{\circ} 14' N.$, lon. $27^{\circ} 50' W.$, to 8 P. M., Dec. 23, lat. $49^{\circ} 03' N.$, lon. $32^{\circ} 50' W.$, encountered a tremendous storm from S. S. E., shifting to West at midnight of the 22d (lat. $39^{\circ} 41' N.$, lon. $30^{\circ} 41' W.$), when the barometer (corrected and reduced) read 27.75. The seas were extremely rough and very high, some of them toppling at a height of thirty feet or more. We tried to keep wind and sea two or three points on the starboard bow, but much water came on board, damaging the starboard boats. Oil was used from bags on the weather bow and from the mid-ship closets, and this prevented the seas from breaking on board.

Data received subsequent to date of publication of the February "Chart" only add to the completeness of the information at hand without materially changing the conclusions already reached. The accompanying map must therefore be of permanent value as illustrating one of the many great storms of the stormy North Atlantic.

THE HURRICANE OF
DECEMBER 22, 1892.
NOON, G. M. T.

SYMBOLS

WIND

○ Calm.

▽ Variable.

○ NE., force 4

○ W., " 6

○ SW., " 8

○ S.W.E., " 12

WEATHER

: Rain.

• Snow. ▲ Hail.

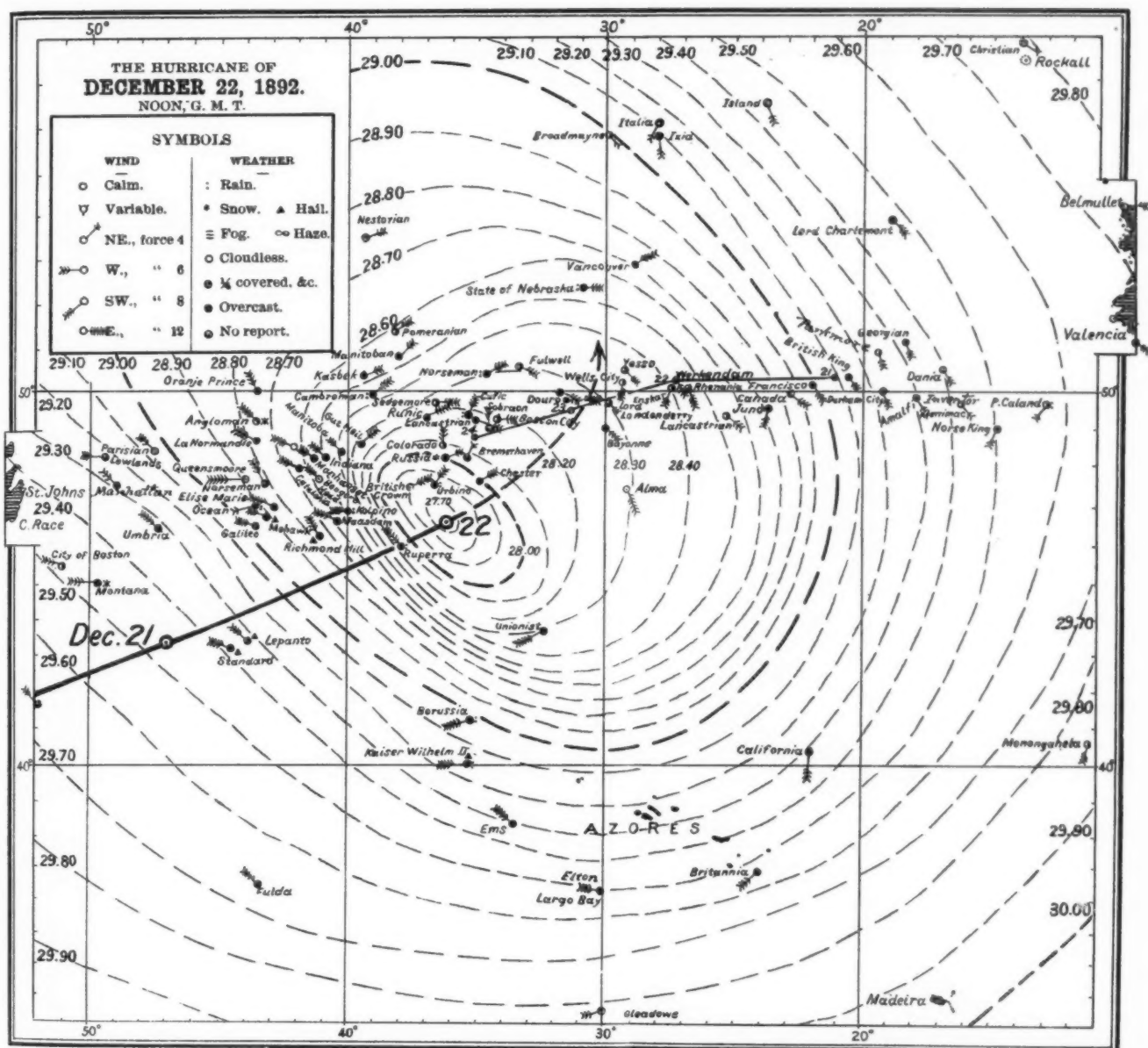
≡ Fog. ∞ Haze.

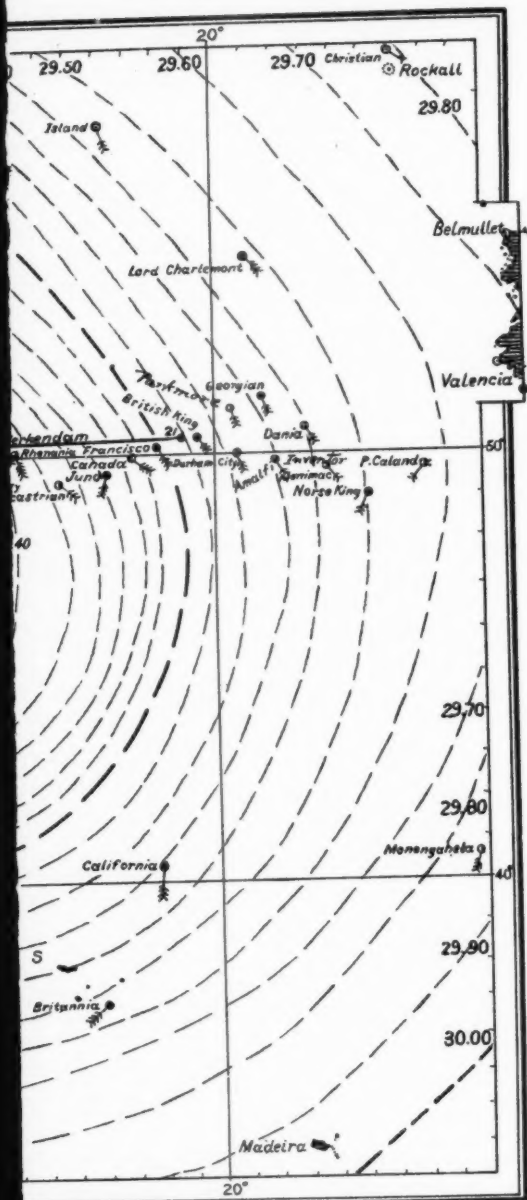
○ Cloudless.

● ½ covered. &c.

● Overcast.

○ No report.





CURRENT NOTES.

New England Meteorological Society.—A joint meeting of the New England Meteorological Society and of the New England Association for Applied Meteorology was held at the Massachusetts Institute of Technology, Boston, on Jan. 27, 1893. Papers were read as follows: R. DeC. Ward, "The Thunderstorms of New England"; J. Warren Smith, "Notes on the Climatology of New England"; Wm. R. Sessions, Secretary of the Massachusetts State Board of Agriculture, "Value of the Weekly Crop Reports"; Prof. Dwight Porter, of the Massachusetts Institute of Technology, "Value of Meteorological Data to the Engineer"; Prof. Mark W. Harrington, Chief of the Weather Bureau, "Exploration of the Free Air"*; Prof. W. M. Davis, "Some Special Difficulties in Weather Forecasting."

Mr. Sessions spoke as follows:—

The Massachusetts Board of Agriculture during the summer months have, by an arrangement with the Weather Bureau, been able to issue the weekly crop and weather bulletin to two thousand of the farmers of the State. To ascertain how well they were appreciated we sent out with the last issue a request that the receiver would indicate to us by postal card whether he wished them continued. The response was favorable in most cases and such expressions as "they are very valuable," "exceedingly interesting," etc., often accompanied the request for continuance.

As suggestions for advance and improvement are in order I would say that, could the crop report cover the States of New York and New Jersey as well as the six New England States, and give particular attention to the condition of the crops most grown for market in Massachusetts, our farmers would be greatly pleased and the value of the bulletins would be materially increased.

The Agricultural Department at Washington obtains careful estimates of the cotton, wheat, oat, and corn crops of the country. These are valuable to the Western farmers, to the transportation companies, to the dealers in these products, and to the exporters of the same, as well as to the commercial and financial world; but the Massachusetts farmer grows none of these for market. His staple crops are hay, apples, small fruits, potatoes and other vegetables. The finer fruits and vegetables are also grown under glass in competition with such products grown in the open air in more southern localities. Consequently he is much more interested in the condition of the Long Island early potato crop and the Aroostook late potato crop than in the outlook for the wheat crop of Dakota, and more interested in the grape crop of central and eastern New York than in the corn crop of

*This paper was printed in the March number of this JOURNAL.

Kansas. The condition of the berry crop of New Jersey is of more importance to him than the cotton crop of the Southern States. The apple crop of western New York interests him much more than the oat crop of Illinois. It would be of value to both the producer and dealer of Massachusetts to know what they must compete with in their business. This is, I take it, the object of the crop report.

Prof. Dwight Porter spoke in substance as follows:—

In the planning of systems of water supply, sewerage and irrigation, estimates of the quantity of water to be dealt with must be made, and these estimates must primarily be based upon recorded observations of rainfall. For certain purposes, knowledge of the annual and of the monthly rainfall and its fluctuations suffices. Even this information is frequently unattainable, in suitable degree, at least. Thus, where it is desired to learn the mean annual rainfall upon a given river basin, it is likely to be the case that rainfall stations are found confined mainly to the valleys, where towns and villages are most numerous and observers naturally most abound, while there are but few records for the more elevated sections, which may differ much from the valleys in respect to rainfall.

In questions of flood discharge of streams, it is desirable to know the depth of precipitation in limited periods during heavy storms,—in periods ranging from a few hours, when dealing with drainage areas in their natural state, down to single hours, or even fractions of an hour, when dealing with the artificial surfaces tributary to sewers.

Knowledge of the rapidity of evaporation from water surfaces, of the pressure exerted by the wind against surfaces, and of other phenomena which it is within the province of the meteorologist to investigate, is also of great value to the engineer.

Prof. W. M. Davis, of Harvard College, read the following paper:—

It sometimes happens that the official weather predictions are at fault, and fair weather comes instead of foul; or still worse, foul weather instead of fair. I recall some particular instances of this kind, which made a strong impression at the time of their occurrence. One was a cold wave in 1886. On a certain morning, a cyclonic centre of moderate activity lay on the coast of Texas, and supposing that it would gradually make its way northeastward, the predicting officer announced fair weather for the following morning in New England. At the time we read that prediction, there was a heavy snow fall, and before the day was over, a violent cold wave was on us.

On another occasion, Thanksgiving Day was called fair in the prediction; and as this day is much of a holiday with us, when persons in town often go out to their families in the country, such a prediction was reassuring for pleasant weather. On the contrary, we had a chilling northeast wind with drizzling rain, extremely unpleasant to all who ventured outdoors.

It is not at all my intention to join the ranks of those who indiscriminately find fault with the work of the Weather Bureau, and who even assert that they could do better themselves. I believe that a brief trial of predictions at regular hours twice a day for definite periods and areas would soon convince these carping critics that prediction is only easy when the signs of weather changes are pronounced; and that in many cases, when the evidence

of change is vague or nearly balanced, specific prediction is extremely difficult. Furthermore, not being successful in local prediction myself, I am ready to recognize that some special mental faculty is needed for the best success in this as in other arts; and hence it is in a manner incumbent on me not to say too much on this subject. My remarks must, therefore, be brief.

Both of the examples of failing predictions, instanced above, resulted from the movements of storm centres in directions or with velocities that had not been anticipated. I believe that this is the chief difficulty that the predicting officers meet with, and that its solution would go far towards removing a considerable class of errors. Now as far as published material informs us, there has been no significant change in method of making weather maps since their first appearance in 1871. It is true that better reductions to sea level are employed for the barometer now, than then; that instruments of higher quality are introduced as far as possible; that the stations are increased in number, but no essentially new principle has been applied to the preparation of the weather maps.

It is also true, as far as I can learn, that no distinctly new method of interpretation from present conditions to future events has been introduced. At the beginning of our weather service, and at present, the general eastward advance of weather areas at an average rate, with certain probable changes in their extent and intensity, has been the guiding principle. The addition of special telegrams from observers on stations when distinct weather changes occur, does not seem to have materially increased the accuracy of predictions, as was hoped.

The increased experience of predicting officers, long on duty, does not bear the fruits that one might have naturally expected of it. For a time, practice on the daily maps makes the work better; but practice in this case does not make perfect work. There are so many elements of the problem missing that we cannot hope to attain perfection; but it is still strange that experience does not tell more than it now appears to. There seems to be a limit of skill that is reached in a few years, and which is not much exceeded after subsequent practice. To what, then, shall the science turn for the better results that are naturally and properly expected from the future?

There does not seem to be good reason for asking for a greater number of stations within the United States. The number now reporting suffices to define all the facts that are at present wanted; although, as has long been said, additional stations on the north in Canada and on the south in Mexico and the West Indies would frequently be serviceable. Yet failures of prediction occur in connection with storms that move directly across our own country, with observers on all sides of them.

The observations of pressure and temperature leave nothing to be desired in the way of accuracy. Humidity is also determined with as much accuracy as is called for. The desideratum in connection with these factors is a repetition of observations at certain definite altitudes above each station on the earth's surface; and this is at present so distinctly unattainable that it need not be considered.

The direction and velocity of the surface wind are in many cases influenced

by neighboring objects, such as hills or buildings ; and it might sometimes be advantageous to have such deflections avoided. This could be done in great measure by the use of a small captive balloon, whose drift would give the mean direction of the wind with much nicety ; but its records would hardly pay for the trouble and expense that they would cause.

An improvement in the observation of clouds seems to me to offer a greater probability of assistance than anything else that is now attainable. At present, their direction and relative velocity are very roughly observed, in spite of the fact that it is only from such observations that we gain any direct knowledge of the movements of the greater atmospheric currents. Instruments of a simple and inexpensive kind, easily used, suffice to determine the direction of cloud drifting with close accuracy, as Mr. Clayton's observations on Blue Hill show so clearly ; and as clouds of certain kinds generally drift within certain limits of altitude, it is possible to convert their apparent angular velocity into actual linear velocity within certain not unreasonable limits of error. When we consider how simply such observations can be made, it is a matter of surprise that they have not been already more generally introduced ; perhaps the reason of this is to be found first in the frequent absence of clouds, or in their presence in so uniform a sheet that their movement cannot be measured ; in their general invisibility at night ; and again in the large share that the personal estimate of the observer must have in determining the results, because he has to decide on the class of every cloud, and on its class will depend its assumed altitude and thus its estimated velocity. Yet, when it is remembered that we have no other means of determining the movements of the upper air, and that the movements of high-level currents must be very influential in determining the path and velocity of storm areas, we must still wonder that a greater effort has not been made to improve and utilize cloud observations. Much new investigation should, of course, accompany the introduction of new data ; and an advance in theoretical meteorology as well as an improvement in weather predictions might be expected from it. The behavior of clouds in their growth, transformation, and dissolution are of importance as well as their movement, but as this cannot be well translated into brief telegraphic cipher, it can, for the present, be available only to the local forecast officials.

The day before the coming of the the cold wave of January, 1886, above referred to, the afternoon sky was crossed by long cirrus streamers of beautiful form. Their movement at the time of the 3 P. M. observations could have been taken with ease. Is it not at least extremely probable that the rapid movement of the cyclone from which they radiated would have been foreshadowed by some peculiarity of their drifting ? In the example of the Thanksgiving Day storm already mentioned, — a storm which ran on to the New England coast from the south, — it is most likely that some indication of its approach could have been gained if the observers on the South Atlantic sea-board had taken close observations of the cloud banks out over the ocean.

When we consider the ingenuity that has been displayed in the development of the weather map, as it now exists, it seems as if the cloud observations here referred to might be so treated as to render much assistance in

difficult cases, when no other means of solving the questions of rate and velocity of storm progression are available; and I believe that they must be resorted to and carefully tried before their present comparative neglect can be warranted.

Prof. C. D. Warner, of Amherst, made the following remarks on Mr. J. Warren Smith's paper on the "Climatology of New England":—

I have been very much interested in the paper read by Mr. Smith, as it treats in part of a subject upon which I have been working. During the past year, I have been reviewing and systematizing the large amount of meteorological data collected by the late Prof. Snell and the Misses Snell of Amherst. Prof. Snell commenced making observations in 1836, and there is an unbroken chain of data covering a period of fifty-seven years. The curves of barometric pressure, temperature for the winter months, summer months, mean yearly temperature, mean rainfall, mean snowfall, have been plotted, and it was found that the minimum pressure with few exceptions occurred in cycles, and that the number of years in these cycles is some multiple or very near some multiple of five. The maximum mean yearly temperature occurred in multiple of six. The maximum mean temperature for the three winter months and the three summer months occurred in cycles of some multiple or very near some multiple of five. The same was observed concerning the maximum rainfall. The curve representing the snowfall was more irregular and indicated no well defined cycle. It was also found that 245.67 feet of snow fell during the period of fifty-seven years, and while the mean yearly temperature for the same time had changed very little, the snowfall during the last eighteen years had gradually decreased.

After the reading of Prof. Davis's paper on "Forecasts," and the question was opened for discussion, Prof. Warner said in substance:—

I have heard a great deal of criticism concerning the inefficiency of the Weather Service and the incompetency of those who do the forecasting, and to satisfy myself regarding the matter, I decided to keep a record of the Boston and Washington daily forecasts and compare them very carefully with the true state of the weather at Amherst. I began the work Jan. 1, 1893, and continued through the year with the following results, which show the percentage of accuracy:—

BOSTON.			WASHINGTON.		
		per cent			per cent
January	93.3	"	87.		"
February	93.1	"	86.6		"
March	100.	"	100.		"
April	93.3	"	80.		"
May	80.6	"	71.		"
June	70.	"	83.3		"
July	88.8	"	87.		"
August	96.7	"	96.7		"
September	96.3	"	96.6		"
October	93.6	"	96.8		"
November	96.6	"	96.6		"
December	90.5	"	88.9		"

Average for the year 1892: Boston, 91.06 per cent; Washington, 89.2 per cent. Difference in favor of Boston, 1.86 per cent.

Dr. S. W. Abbott, of the Massachusetts State Board of Health, sent the following notes:—

The work of the Weather Service has proved a valuable aid to the State Board of Health, since Meteorology and Public Hygiene are allied sciences.

The State Board of Health has, for the past ten years, published an annual summary of its observations upon the prevalence of infectious diseases throughout the State, in connection with the weekly observations as to temperature, rainfall, etc.

In the study of the very important subject of water supplies, which now constitutes a prominent feature of the work of the Board, it has become a matter of absolute necessity to know with exactness the amount of yearly rainfall, especially in those densely settled parts of the State where communities are constantly seeking for larger and purer supplies of water.

The New England Weather Service has furnished its observations regularly to the Board, weekly, monthly, and also annually. The weekly returns have been regularly published in the weekly bulletin of mortality issued by the Board; the printed monthly bulletins are kept on file at the office for the use of all departments of the Board, and especially for the Engineering Department, and the annual statement has been used for publication in the Registration Report, the editing of which, for the five years (1886-1890) was under the supervision of the State Board of Health.

Royal Meteorological Society.—The usual monthly meeting of this Society was held on Wednesday evening, Dec. 21, at the Institution of Civil Engineers, 25 Great George Street, Westminster; Dr. C. Theodore Williams, president, in the chair.

The following papers were read:—

(1.) "Moving Anticyclones in the Southern Hemisphere," by Mr. H. C. Russell, F. R. S., Government Astronomer, New South Wales. The author describes the results of his practical study of the daily Weather Charts for Australasia, and states that the leading fact brought out is that the weather south of twenty degrees south latitude is the product of a series of rapidly moving anticyclones, which follow one another with remarkable regularity, and are the great controlling force in determining local weather. These anticyclones are more numerous in summer than in winter; the average number for the year being forty-two. They usually take seven or eight days to travel across Australia in summer, and nine or ten days in winter; the average daily rate of translation being four hundred miles. The shape of the anticyclone appears to undergo some modification as it nears the east coast. The winds on the north side of the anticyclone are not so strong as those on the south side, and the intensity of the weather is in proportion to the difference in pressure between the anticyclone and the V-depression, but the relation of the pressures varies frequently before the wind responds, the pressure appearing to be controlled from above by the more or less rapid descent of air which feeds the anticyclone. Cyclonic

storms are very unusual, and do not occur more than once in two or three months.

(2.) "The Tracks of Ocean Wind Systems in transit over Australasia," by Capt. M. W. C. Hepworth, F. R. Met. Soc. The author has examined the daily Weather Charts of Australia and New Zealand, and has prepared maps showing the daily positions of the centres of high and low pressures for a whole year. He finds that the wind systems, which make their first appearance to the westward and southwestward, advance to the eastward rapidly, and frequently very rapidly, during the winter months; but during the summer months they usually move more slowly and not unfrequently recurve. Their progress is retarded by contact with the areas of high pressure which they encounter; the mean of the tracks of these anticyclones, moving also from west to east, appears to be across the southern portion of Australia and onward, crossing the islands of New Zealand during the winter months; but to the southward of Western and South Australia, across Victoria and New South Wales, and thence to the north-eastward, avoiding New Zealand during the summer months.

(3.) "Rainfall of Nottinghamshire, 1861-90," by Mr. H. Mellish, F. R. Met. Soc. The author has collected and discussed all the rainfall records made in the county during the thirty years, and finds that in the extreme west the mean rainfall is twenty-seven inches or more, and that over the rest of the county it varies between twenty-five and twenty-seven inches, except north of the Manchester, Sheffield & Lincolnshire Railway, where the rainfall is less than twenty-five inches, and in the northeast towards Gainsborough where it is not more than twenty-three inches. The year of greatest rainfall was 1872, and of least rainfall, 1887. October is the wettest month and February the driest.

(4.) "A New Instrument for Cloud Measurements," by Dr. Nils Ekholm, Hon. Mem. R. Met. Soc.

The annual meeting of this society was held on Wednesday evening, Jan. 18, at the Institution of Civil Engineers, 25 Great George Street, Westminster, Dr. C. Theodore Williams, President, in the chair. After the report had been read, and the officers and council for the ensuing year had been elected, the president delivered an address on "The High Altitudes of Colorado and their Climates," which was illustrated by a number of lantern slides.

Dr. Williams first noticed the geography of the plateaux of these regions, culminating step by step in the heights of the Rocky Mountains, and described the lofty peaks, the great parks, the rugged and grand cañons, and the rolling prairie, dividing them into four classes of elevations between five thousand and fourteen thousand five hundred feet above sea level. He then dwelt on the meteorology of each of these divisions, giving the rainfall and relative humidity, and accounting for its very small percentage by the moisture being condensed on the mountain ranges of the Sierras lying to the west of the Rockies; also noticing the amount of sunshine and of cloudless weather, the maxima and minima temperatures, the wind force and the barometric pressure. Dr. Williams quoted some striking examples of electrical phenomena witnessed on Pike's Peak (fourteen thousand one hundred

and forty-seven feet), by the observer of the United States Weather Bureau, when during a violent thunderstorm flashes of fire and loud reports, with heavy showers of sleet, surrounded the summit in all directions, and brilliant jets of flame of a rose-white color jumped from point to point on the electric wire, while the cups of the anemometer, which were revolving rapidly, appeared as one solid ring of fire, from which issued a loud, rushing and hissing sound. During another storm the observer was lifted off his feet by the electric fluid while the wrist end of his woollen shirt, as soon as it became damp, formed a fiery ring around his arm. The climate of the parks is, however, Dr. Williams considered, of more practical interest; and in these magnificent basins of park-like country, interspersed with pines and backed by gigantic mountains, are resorts replete with interest for the artist, the sportsman, the man of science, and the seeker for health. Most of them lie at heights of from seven thousand to nine thousand feet, and so good is the shelter that usually snow does not long remain on the ground; while Herefordshire cattle in excellent condition are able to fatten on the good herbage, and to lie out all the winter without shed or stable. Dr. Williams predicted for these parks a great future as high altitude Sanitaria for the American continent, especially as several of them have been brought within easy distance of Denver, the Queen City of the Plains, by various lines of railway. The resorts on the foot-hills and on the prairie-plains, at elevations of five thousand to seven thousand feet, include, besides Denver, Colorado Springs, Manitou, Boulder, Golden, and other health stations, which can be inhabited all the year round; and where most of the comforts and luxuries of American civilization are attainable in a climate where not more than half a day a week in winter is clouded over, where the rainfall is only about fourteen inches annually, most of which falls during summer thunderstorms, where the sun shines brightly for three hundred and thirty days each year, and where the air is so transparent that objects twenty miles off appear close at hand, and high peaks are calculated to be visible at a distance of one hundred and twenty miles. Dr. Williams summed up thus: The chief features of the climate of Colorado appear to be: 1. Diminished barometric pressure, owing to altitude which throughout the greater part of the State does not fall below five thousand feet. 2. Great atmospheric dryness, especially in winter and autumn, as shown by the small rainfall and low percentage of relative humidity. 3. Clearness of atmosphere and absence of fog or cloud. 4. Abundant sunshine all the year round, but especially in winter and autumn. 5. Marked diathermancy of atmosphere, producing an increase in the difference of sun and shade temperatures varying with the elevation in the proportion of one degree for every rise of two hundred and thirty-five feet. 6. Considerable air movement, even in the middle of summer, which promotes evaporation and tempers the solar heat. 7. The presence of a large amount of atmospheric electricity.

Thus the climate of this State is dry and sunny, with bracing and energizing qualities, permitting outdoor exercise all the year round, the favorable results of which may be seen in the large number of former consumptives whom it has rescued from the life of invalidism and converted into healthy active workers; and its stimulating and exhilarating influence may also be

traced in the wonderful enterprise and unceasing labor which the Colorado people have shown in developing the riches, agricultural and mineral, of their country.

Weather Forecasts by Electric Flash-Light.—A novel scheme for disseminating the daily weather forecasts was inaugurated on Sept. 12, 1892, in New England. An electric search light, of the kind used on men-of-war, having been placed on Mt. Washington, in New Hampshire, by the Thomson-Houston Company, an arrangement was made between Mr. J. W. Smith, Local Forecast Official at Boston, and Mr. L. H. Rogers, who owned and managed the light, whereby the forecasts could be spread by means of the light. Forecasts were sent from Boston about noon by telegraph to Mt. Washington, and in the evening were flashed over the surrounding country by the light. The code adopted was as follows:—

FLASHES.	INDICATE.
One long	Fair weather.
Two long	Rain or snow.
Three long	Local rains.
One short	Lower temperature.
Two short	Higher temperature.
Three short	Frost warning.

The flashes for weather were given first, and when no short flashes were given it indicated stationary temperature. The flashes were directed to every point of the compass in succession, and when the circle was completed, they were repeated, to avoid the chance of error. This system of flashing the forecasts was continued from Sept. 12 to Oct. 1, when the light was discontinued for the season. Reports received from persons in the vicinity of the mountain show that the plan was quite successful, and the flashes were reported to have been seen at a distance of eighty miles. It is intended to resume the work next summer.

Weather Forecasts by Railway from Boston, Mass.—On Aug. 22, 1892, a system of sending weather bulletins by railway was inaugurated in New England, through the energetic efforts of Mr. J. W. Smith, Local Forecast Official, at Boston, Mass. By this arrangement there are sent out daily, at the present time, from the Boston office of the Weather Bureau, 300 printed forecasts of the weather for forty-eight hours, based on the 8 A. M. observations. Besides the forecast the bulletin contains a short synopsis of the weather conditions over the country. The bulletins are distributed from the trains, and posted immediately on receipt, in the various railway stations, in neat frames provided for the purpose by the Weather Bureau. In this way the forecasts are brought before the public in as short a time as possible, and being posted in the railway stations are accessible to a large number of persons. At present the Old Colony Railroad is the only one which distributes these bulletins, but Mr. Smith hopes soon to be able to send them out over all the railroads which run from Boston.

Meteorological Observations from Balloons.—Referring to the need of observations in the upper regions of the atmosphere, the Secretary of Agriculture says in his last annual report: "We must now have also in meteorology observations of the conditions prevailing in the upper air strata. The policy of the Bureau has looked, therefore, to the re-establishment of high-level stations, and the station at Pike's Peak has been reopened. Nevertheless, all the requirements of modern meteorology cannot be fully met by mountain stations. We need a certain number of observations made in free air, and for this purpose balloons seem to be the only means at present available." In this connection Prof. Mark W. Harrington, the chief of the Weather Bureau, has recently made the following suggestion in the *Chicago Herald*:—

"This brings us face to face with the arts of ballooning, artificial flight, and all the complex problems of aeronautics and aerodynamics. In any case it seems evident that aeronautics has not yet reached the stage at which it appears to the lawmakers as a matter demanding the expenditure of public money, and it must rely on private beneficence. Under these circumstances it would appear that the popular interest in the matter and the great possibilities for commerce and war which aeronautics presents, combined with the certainty that its investigation would result in any case in the perfection of the science of the weather, would justify some broad-gauged, liberal-minded, wealthy Chicagoan in establishing an institute for aeronautics. It is a splendid opportunity to do good to the world and establish a monument to one's self—a monument which, though built in the air, would be *acre prennius*."

The Influence of the Moon on Rainfall.—In *Science* for Dec. 2, 1892, there are two articles on the influence of the moon on rainfall which deserve mention. The first is by Mansfield Merriman, Ph. D., of Lehigh University, South Bethlehem, Pa. As is well known, there is a widespread belief that thunderstorms are affected in their occurrence and in their movements by the moon, and that clouds are dispersed under the influence of the full moon. The author has taken the records of rainfall kept at Bethlehem, Pa., during 1881–1890, as the basis of the discussion. His first conclusion is that the rainfall is liable to increase after the new moon; the second, that the full moon is generally followed by a decrease in rainfall; the third and fourth that the wettest period in the lunar month is near and before the full moon, and that the driest period is near and before the first quarter.

The second article is by Prof. H. A. Hazen, of Washington, D. C. Prof. Hazen states that the question has been thoroughly investigated in England and Europe with a negative result, except that there seems to be a slight influence of the moon, or perhaps the tide, on the occurrence of thunderstorms, and that the full moon seems to have the power to drive away clouds. The author has computed the data of rainfall at Philadelphia, Pa., for fifteen years, 1871–1885, and then for the ten years, 1882–1891. In the first period of fifteen years there is a preponderance at the time of new moon. In the second period, for the three days about each phase, Prof. Hazen's result is similar to that of Dr. Merriman.

Thunderstorms and Sun-Spots.—A correspondent writes to *Nature* (Sept. 22) regarding the relation between sun-spots and thunderstorms. The thunderstorm records for Berlin from 1850 and for Geneva from 1852 are grouped and curves are drawn. It appears from a comparison of these curves with the sun-spot curve that the maxima of the sun-spot curve correspond to the minima of the thunderstorm curves. In 1874 Prof. von Bezold came to the conclusion that "high temperatures and a spotless solar surface give years abounding in thunderstorms," and these results bear out his statement.

NOTICE.—The undersigned wishes the addresses of those who are interested in the modern dynamic physical and mathematical meteorology; especially those who will perhaps introduce this study into college and university classes. Those who desire a copy of the "Mechanics of the Atmosphere," recently published by the Smithsonian Institution may apply to

CLEVELAND ABBE,
Washington, D. C.

CORRESPONDENCE.

THE NEEDS OF METEOROLOGY.*

WASHINGTON, Jan. 23, 1893.

Editor of the American Meteorological Journal:

WITHIN the past thirty years all branches of science have made remarkable progress and some have become so prominent as to seem like wholly new creations; this is notably the case with electricity and meteorology. The study of electricity is not only opening up to us a deeper insight into the ultimate properties of the molecules of matter but is accompanied by such important and varied applications to the arts of civilization that we are rapidly passing from the "Age of Steel" to the "Age of Electricity." Such progress has evidently only become possible through the fact that the physical laboratories of the world have turned our attention so largely to the purely scientific investigation of electrical laws. We must first know the laws of nature before we can apply them to human needs. The scientist must discover before the inventor can apply.

Both governments and private individuals have, these many years, vied with each other in stimulating physical, chemical, and astronomical science. These have been encouraged in the great universities where laboratories and observatories have been equipped with the finest apparatus and provided with the most learned mathematicians and the most skilful experimenters. Thousands of students have been attracted by these studies and it is now well recognized, in these departments, that great advance is only likely to be made by those men who, to inherited gifts, have added great advantages of study and training. So well is this understood that it has even become customary for the wealthy to erect to themselves monumental observatories and laboratories, university chairs and prize funds, devoted to the furtherance of physics and astronomy.

But there is one subject of importance to mankind that has, it seems to me as yet received only partial and imperfect recognition. Although meteorology has always been recognized as of the highest utility yet it is not studied in our universities and scientific schools on a scale commensurate with its practical importance. As soon as it was feasible to make daily weather maps, from daily telegraphic reports, the governments of the world established their weather bureaus on a scale proportionate to the material interests involved, and now for nearly forty years the art of predicting the weather

*The editor of this JOURNAL requests that this communication may be given as wide a circulation as possible and that it may be reprinted in the various State Weather Service publications, as well as in the daily press.

has gradually been improved upon; this work is done by empirical methods quite analogous to those which the ancients employed in the predictions of solar eclipses.

What meteorology needs is that its methods should be perfected by experimental work similar to that done in the physical laboratories, and by mathematical work similar to that done in astronomical institutions. It is high time that we began to pass from the empiric to the philosophic methods, but I see no prospect of doing this unless our universities give the young men, who are in special training for the pursuit of the exact sciences, full opportunity to acquaint themselves with the beauty and the importance, the difficulties and the possibilities of the problems of meteorology.

There are in this country a dozen institutions of learning which offer young men the highest education in mathematics, chemistry, physics, and astronomy; why not also in meteorology? Each of these has from fifty thousand to five hundred thousand dollars invested in astronomical apparatus with only, here and there, one or two special students in this science. Equal amounts are invested in chemical and physical laboratories; many students take these courses and an appreciative knowledge of these subjects begins to pervade the community; but, of course, only very few of these students take up these studies as their life-long profession.

To any one who desires to increase the attractiveness of his university or to be a benefactor to science, or to establish a monument honorable to himself, or to invest a large sum of money in a manner that will never be regretted, I would say do for meteorology and terrestrial magnetism that which has so often been done by others for other sciences. Give your name and your fortune to a meteorological laboratory in connection with some one of our best-endowed universities; call around you a few able investigators with every appliance for increasing our knowledge in this branch of science; let the young men of our country understand that after proper, thorough preparation, they may at your institution perfect themselves in this study.

Our government and State weather bureaus are established for *doing work* and not for giving instruction; they will need to employ the students whom you graduate from your school of meteorology. Just as the learned astronomers of our universities and observatories have built up a recognized science of astronomy which the practical navigator and surveyor brings into daily use in his work, so will learned professors in such schools of meteorology constitute a body of leaders in scientific thought to whom the youth of the country will inevitably resort for instruction.

Who will be the first to establish an American school of meteorology?

I know of no more inviting field than this for the investment of funds that are to be devoted to the intellectual progress of our beloved country. That I am not alone in my opinions is evident from the fact that on mentioning my convictions to a friend, eminent in both educational and practical matters, he replies: "There is certainly very great need for such a department not only for its own sake but for the sake of kindred departments. We feel it very much in geology, and have been discussing the propriety of introducing temporarily, as a part of our department, courses on the salient features of

meteorology. We feel that we cannot develop the 'new geology' satisfactorily without it. We would welcome most heartily the establishment of an independent fully developed meteorological department, such as you outline, and I hope we shall be able to secure it at an early date." So deeply does the importance of the subject commend itself to my judgment that if any one desires to have a more detailed plan of work, I should be glad to assist in elaborating it. If a further assurance of unselfish interest in the matter is desired, I may add that I have a scientific library of five thousand or six thousand books and pamphlets that I should be pleased to donate to a well-endowed meteorological institute connected with either Harvard or Yale, Columbia or Johns Hopkins, Michigan or Chicago, or other university of similar rank where the auxiliary physical and mathematical sciences are properly taught.

CLEVELAND ABBE.

CLOUDINESS DURING SOLAR ECLIPSES.

Editor of the American Meteorological Journal :

It is so easy for one to do an original piece of work under the impression that he is also doing something that is quite new, that one ought to look very charitably upon such accidents; it is better for a student to duplicate another's work rather than not to do any work at all, but it is still better to look over the literature of any subject before claiming priority as well as originality.

On page 379 there occurs a sentence beginning "For the first time this has been done for the total eclipse of 1893, etc."; if this means that Prof. Todd's excellent article is the first collection of data that has been made relative to the eclipse of 1893, then the statement may be correct, but if, as the context seems to imply, it means that this is the first occasion on which a systematic examination of cloud conditions has been made for the purpose of selecting observing stations, then it is quite erroneous. Not to mention numerous earlier cases in which such work has been done more or less completely I may especially call attention to the circulars compiled by myself for the use of American astronomers early in 1878, showing the probable chances of fair observing weather for the eclipse of July 29. Copies of this circular were distributed to all astronomers in April of that year, and it will be found reprinted at page 813 of the Annual Report of the Chief Signal Officer for 1880, as also in the reprint of my report on the total eclipse which appeared as Professional Papers of the Signal Service.

In Chap. IV. of that report, or page 897 of the Report of the Chief Signal Officer for 1880, I have shown that on the average of all stations along the whole path of totality the predicted percentage of favorable weather was eighty, while the actual percentage, as observed on the day of the eclipse, was seventy-six. I doubt not that Prof. Todd's predictions, based on the meteorological records published by him, will show an equally satisfactory agreement with the actual weather on the 16th of April next.

CLEVELAND ABBE.

WASHINGTON, Jan. 16, 1893.

THE APPROACH OF COLD WAVES.

Editor of the American Meteorological Journal:

There is one indication of the approach of cold waves which several years' observation leads me to believe is very reliable, but which I have never seen alluded to in meteorological publications, and that is the occurrence of snow flurries succeeding rain or during mild spells in winter. I have noticed that on such occasions they are nearly always succeeded by a decided fall in temperature, as much as fifteen to twenty degrees.

This happened three times during the past month. On Dec. 20, rain changed to show, and temperature fell from maximum of 38° to minimum of 16° within twenty-four hours.

On the 24th, snow flurries occurred with thermometer at 25° . By the following morning it had dropped to 9° . On the 26th, a snow squall occurred in the evening and the temperature fell from 23° to 8° by the next morning. Other instances might be cited but these are sufficient to illustrate my meaning. If this has been sufficiently observed elsewhere, so as to be confirmed as a general rule, good use might be made of it by shippers of fruits, vegetables, etc., and in care of farm stock where the government warnings of cold waves may not be received in time.

JOHN H. EADIE.

BAYONNE, N. J., Jan. 3, 1893.

EFFECT OF HIGH WINDS ON THE BAROMETER.

Editor of the American Meteorological Journal:

In the February number of this JOURNAL, page 463, Mr. Lyons closes his letter on the effect of the wind on the barometer by suggesting a little judicious experimenting. In the top of the tower of Blue Hill Observatory is a trap door, and by opening this during gales of fifty to sixty miles an hour, barographs (both mercurial and aneroid) in the room beneath will record a fall of from five hundredths to a tenth of an inch, the fall being evidently due to a suction produced by the air blowing across the mouth of the aperture, which is horizontal. When the trap door is closed the barometers will record at their former level. When windows are opened on the windward side the barometer will show sudden rises of equal amount. Diagrams showing specific instances will be found in the Blue Hill Annals for 1886 and 1887, and a discussion of this subject in the copies of *Science* between May and October, 1886.

H. H. CLAYTON.

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THE TOTAL SOLAR ECLIPSE OF JAN. 1, 1889.

WINSLOW UPTON AND A. LAWRENCE ROTCH. *Meteorological and other Observations made in Connection with the Total Solar Eclipse of Jan. 1, 1889, at Willows, California.* Extracted from Vol. XXIX. of The Annals of the Astronomical Observatory of Harvard College, Cambridge, 1892. 4to, pp. 34, plate I.

These observations were made in part by self-registering apparatus and in part by frequent readings of ordinary instruments, at the town of Willows, Coluso County, California, on a tower thirty-eight feet high, and about two thousand seven hundred feet west-northwest from the station occupied by the Harvard Observatory party. The meteorological observations were especially directed towards the subject of barometric pressure, air temperature, humidity, solar radiation, wind direction, and wind velocity. It appears from the table of reduced barometer readings that during the eclipse there was a fall and then a rise of pressure. The minimum was reached twenty minutes after totality, and the rise after the eclipse was slow, exhibiting several minute fluctuations. The course of the pressure in this case, seems to resemble the regular diurnal fluctuation. The general similarity of the pressure curves on Dec. 31 and Jan. 1, in the absence of any more precise knowledge of the regular diurnal barometric fluctuations at the station, indicates that the general course of the pressure at the time of the eclipse was what would have happened had the eclipse not occurred. This is further confirmed by a comparison of the Willows observations with those made at Red Bluff, Sacramento, and Winnemucca. The air temperature fell 6°, the minimum being reached ten minutes after the close of totality. At its minimum the reading was 5° higher than the calculated dew-point. The rise in temperature after the eclipse was rapid, the maximum being reached at about 3.15 P. M. During the eclipse the dew-point rose from 33° to 41°; after the eclipse it fell to 36°. The relative humidity rose 30 per cent, but its maximum was 19 per cent below saturation. The black and bright bulb thermometers show that the solar intensity was greatest at 12.15 P. M. It diminished rapidly before the beginning of the eclipse, due to the clouds in the sky. Some heat was received throughout the total phase, the minimum being reached five minutes after totality, at which time the black bulb *in vacuo* was three degrees above the air temperature. The wind gradually changed during the eclipse from a direction west of north to one east of north, and there was a distinct fluctuation in its movement. It is not improbable that these fluctuations may be explained as due to the effect of the eclipse, for the withdrawal of the sun's heat would certainly produce atmospheric fluctuations, and these in turn ought to affect the direc-

tion of the wind. The velocity of the wind decreased from twelve miles an hour to almost a calm.

While the whole of this report is interesting to the meteorologist, perhaps the most striking point in it is the change in wind direction during the eclipse. Such "eclipse winds," if they really occur, although of course a very unimportant class, deserve a place in a systematic classification of the winds, such as that given by Prof. W. M. Davis in this JOURNAL, Vol. IV., 1887-88, page 512. They should be placed under the head of winds due to the sun's action.

FLUCTUATIONS IN THE LEVEL AND RATE OF MOVEMENT OF GROUND-WATER.

FRANKLIN H. KING. *Observations and Experiments on the Fluctuations in the Level and Rate of Movement of Ground-Water on the Wisconsin Agricultural Experiment Station Farm, and at Whitewater, Wisconsin.* United States Department of Agriculture, Weather Bureau, Bulletin No. 5, 8vo. Pages 75; plates VI. Washington, 1892.

We regret very much that our notice of this most interesting and suggestive pamphlet has been so long delayed. This, the fifth in the series of Bulletins published by the Weather Bureau, gives the results of a series of observations, begun in July, 1888, on the fluctuations and rate of movement of ground-water, a subject that has as yet received comparatively little attention, and which presents a most attractive field for further research, especially at the various State Agricultural Experiment Stations. The instrument used in measuring the changes in the level of the ground water, consisting of a chain with numbered links of uniform length, carrying a heavy poise at one end and provided with a micrometer at the other, measures with certainty changes in level of the water of less than .03 inch. The wells used in the experiments were about fifty in number. Of the many facts of interest brought out in Prof. King's report we can mention only a few. Perhaps the most interesting point for meteorologists to consider is the relation of the fluctuations of ground-water to the changes in barometric pressure, which has been well worked out by the author. It appears that a "generalized curve representing the fall of water in a well would have a form such that the steeper slopes span intervals of rising barometer and the less steep ones periods of falling barometer." In order to obtain comparable results, automatic records of the fluctuations in the level of the ground-water were kept, the self-recording instruments used consisting of a drum carrying a record sheet, driven by clock work. On this sheet, by a system of levers, a pen worked by a float on the surface of the water, traces a continuous record, as in the case of the barograph or the thermograph. A comparison of some of these automatic ground-water level curves and of barograph curves made at the same times, shows a most marked correspondence, and makes it clear that barometric changes exert a far-reaching influence upon underground drainage, and an almost immediate influence upon the level of water in wells. A rise of the barometer is associated with a fall of the water, and

a fall of the barometer with a rise of the water level. It appears further that long-period barometric changes, and perhaps all barometric changes, have a greater influence on the water of deep wells than on that of shallow wells. The changes in the temperature of the soil are also accompanied by changes in the movement of water in the soil. The passage of a heavily loaded train near a well produces sudden sharp rises in the level of the water in the well, a possible explanation of this fact being found in the depression of the earth by the train, causing it to sink into the ground-water, thus displacing the latter laterally and causing it to rise in the surrounding area.

Prof. King closes his report with some suggestions for further study. He says: "A careful and detailed study of the movements of ground-water ought to supply very important knowledge bearing upon the contamination of drinking waters and the spreading of certain classes of contagious diseases, and thus help to place the water supply for both urban and rural purposes under better sanitary conditions. Every advance which is made toward the increase of yield per acre necessarily means an increased demand for water, so that market gardeners even in Wisconsin and Illinois, where both the annual and summer rainfall is relatively large, are turning their attention toward providing suitable means for irrigation; and a rapid and economical advance in this direction demands a much more thorough knowledge of the movements of underground water than we at present possess. In the utilization of natural subirrigation, to which reference has been made, and in the reclaiming of swamp lands for agricultural purposes, which must be of growing importance in the immediate future, there is imminent need for new knowledge in the same direction."

We recommend this report to all our readers, who we are sure will find it both interesting and instructive. It is illustrated by many diagrams and plates, and is written in a style which makes it easy of comprehension by the average reader, and at the same time presents the facts in a careful and thoughtful way.

THUNDERSTORMS, AURORAS, AND SUN SPOTS.

M. A. VEEDER. *Thunderstorms*. Extracted from the Proceedings of the Rochester Academy of Science, Vol. 2. Rochester, 1893. 8vo, pages 148; plate I.

Dr. Veeder has been so earnestly active in gathering statistics concerning the aurora that he may be considered as having to a great degree made the subject his own. He has repeatedly published tables to show a periodicity of the aurora corresponding to the time of the rotation of the sun on its axis, and in the present paper gives a table in which the number of stations recorded in the "U. S. Weather Review" as reporting auroras were tabulated for each day from February, 1885, to December, 1888, divided into periods of twenty-seven days, six hours and forty minutes, corresponding with a solar rotation. A study of this table and of preceding ones given by Dr. Veeder, scarcely leaves room for doubt that there is a periodicity in the aurora corresponding to a solar rotation. He claims that the occur-

rence of auroras is coincident with the appearance of spots on the eastern limb of the sun, but furnishes no data to prove this point.

The object of the present paper appears to be to suggest that thunderstorms have a periodicity like auroras, and have a reciprocal relation to auroras, the one taking the place of the other under certain circumstances. He, however, furnishes no data to sustain this. In fact the fault to be found with the entire remainder of his paper is that he gives many conclusions without any adequate data to sustain them.

H. H. C.

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4. *Sur l'anomalie magnétique du Bassin de Paris.* Par M. Th. Moureaux.
5. *Sur la détermination du champ magnétique terrestre.* Par M. E. Mascart.
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9. *Sur le gradient barométrique vertical.* Par M. Léon Teisserenc de Bort.

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 3. E. Leyst. *Ueber die Berechnung von Temperatur-Mitteln aus Beobachtungen zu den Terminen, 8 Uhr Vm., 2 Uhr und 8 Uhr Am.* 35 pp.
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 8. E. R. Assafrey. *Magnetische Beobachtungen in Jellissawelpolschen und Bakuschen Gouvernment im Jahre 1890.* 15 pp.
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EDITORIAL NOTE.

WITH this number the present volume of this JOURNAL comes to a close. It seems fitting, therefore, to call the attention of our readers to a few facts concerning the past year. Since the removal of the JOURNAL from Ann Arbor to Boston in May, 1892, the number of subscribers has increased steadily, although slowly, and we feel encouraged at the prospect with which the new volume opens. The larger range from which contributions are being received and the many letters of approval from distinguished foreign meteorologists, as well as from our readers in this country, are signs that the JOURNAL is filling a place which ought to be filled, and is doing so in a satisfactory manner.

While we are pleased at the success of the past year we have not yet attained the goal towards which we are striving. In the volume which is to begin with the next number we propose to improve the JOURNAL in many ways. The general high character of the original articles which have appeared in the ninth volume will be continued in the tenth, and we expect a greater number of contributions from foreign writers, many of whom have spoken of the JOURNAL in the highest terms. As the interest in the science of meteorology in its various branches increases, and as it is more widely taught in our educational institutions, we hope to receive larger numbers of articles from our own country also. With more time at our disposal in the present year than we had in the last, we shall be able to give our readers a fuller account of the work that is being done in meteorology all over the world than it has been possible for us to do hitherto. We shall hereafter endeavor to give abstracts of all the most important foreign papers which appear in the leading meteorological journals of Europe.

Among the articles for which we have already arranged, and which will appear in the next volume, the following may be mentioned : —

- Prof. W. M. DAVIS. "The Winds of the Indian Ocean."
Prof. CLEVELAND ABBE. "Charts of Storm Frequency."
Prof. C. F. MARVIN. "A Proposed Method of Recording Intensity of Daylight." "Results of Anemometer Comparisons." "An Examination of Records of the Vertical Movement of the Atmosphere."
Prof. VON BEZOLD (translated by Prof. Abbe). "Meteorology as the Physics of the Atmosphere."
H. HELM CLAYTON. "Cloud Movements in Cyclones and Anticyclones."
R. DEC. WARD. "Recent Foreign Studies of Thunderstorms." "The Effect of Topography upon Thunderstorms."
G. B. MAGRATH. "The Sea Breeze at Boothbay Harbor, Me."

Also the following contributions from the Laboratory of Physical Geography of Harvard College : —

"Studies of Seiches (Lake Oscillations) in Europe and America," by E. B.

Perkins; "Seiches on Lake Skaneateles, New York," by S. M. Ballou; "Charts of Equal Annual Temperature Ranges based on Buchan's 'Challenger' Charts," by J. L. S. Conolly, and "Charts of Isanomalous Temperatures, based on Buchan's 'Challenger' Charts," by S. F. Batchelder.

A paper is also expected from Dr. Charles Meldrum, of the Royal Alfred Observatory, Mauritius, on "The Incurvature of the Winds in Cyclones."

We hope that our readers will make the JOURNAL as widely known as possible, and will secure for it a wider circulation. The price has been purposely kept at the low rate of \$3 a year in order that the JOURNAL may be generally taken by all persons who are interested in the science of meteorology, although the expense of issuing the paper in its present form is very considerable. We would, therefore, urge all those who have any interest in the science to support the JOURNAL during the coming year.

ERRATA.

On page 37, seventh line from the bottom, for "1879" read "1870."

On page 45, eighth line from the bottom, insert the word "number" after the words "in the December."

On page 414, in the last line of the foot-note, for "October 21" read "October 26."

On page 421, in the foot-note, for "October 21" read "October 26."

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"The Physical Conditions of the Waters of the English Channel," by H. N. Dickson, F. R. S. E. Reprinted from the "Scottish Geographical Magazine" for January, 1893. Pp. 12; plates II.

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